

The Intel® IA-64 Processor Family

A Multi-Operating System Architecture



Introduction

Intel designed the IA-64 family of processors, starting with the Intel® Itanium™ processor, with one idea uppermost in mind: to support and enhance the operation of high-end applications on a variety of operating systems. Consider just a few of the innovations delivered by IA-64:

- For unprecedented levels of performance and scalability, IA-64 provides floating-point extensions, large-memory addressability, expanded registers, multiple pipelines and parallel-execution. These capabilities support the management of peak workloads and complex online transactions and the storage, delivery and analysis of massive volumes of data.
- For the availability essential to e-Commerce, telecommunications and other 24x7 applications, IA-64 provides on-chip parity protection and ECC protection, Enhanced Machine Check Architecture (MCA), an on-die thermal sensor and a fault-resilient boot. These capabilities help administrators identify, contain and correct errors without disrupting service.
- For serviceability, IA-64 provides integrated hot-plug controllers and hot-swap disks. These capabilities enable installation of add-in cards without requiring a system shutdown.

To maximize the benefits of these innovations for vendors and customers alike, industry leaders are working in collaboration to manage the transition to IA-64. They're establishing a foundation for

Table of Contents

Introduction	2
Industry-enabling Efforts	3
<i>Developers' Interface Guide for IA-64 Servers (DIG64)</i>	3
<i>UNIX Developer's Interface Guide for IA-64 Servers (UDIG)</i>	4
<i>UNIX Developer's Guide—Programming Interfaces (UDG-PI)</i>	4
<i>Hardware Design Guide for Windows NT Server (HDG)</i>	5
Major Operating System Initiatives	5
<i>HP-UX (Hewlett Packard)</i>	6
<i>Linux (Trillian Project)</i>	7
<i>Modesto (Novell)</i>	7
<i>Monterey (IBM and SCO)</i>	8
<i>Windows 2000 (Microsoft)</i>	9
Heading in the Right Direction	9

strong and sustainable network platforms and a vibrant marketplace of reliable, interoperable server solutions. They're also removing obsolete technologies and addressing issues that could cause legacy problems as IA-64 continues to evolve.

In particular, hardware and software vendors are working to optimize solutions for the IA-64 processor family, for example:

- Application developers are enhancing and refining systems in the areas of e-Commerce, data mining, high-performance graphics, complex mathematics, visualization and other demanding computing environments.
- Internet-infrastructure developers are creating directory, security, proxy, messaging and transaction-processing services and cache and Web servers.
- Major operating system vendors are porting their existing systems to IA-64, and one vendor is creating a new system for the platform.

Your company or department may be involved one or more of such endeavors, or you may be curious to learn more about how other companies are involved. Whatever the reason for your interest, you'll find this document useful in a number of ways.

For instance, in it you'll learn about the major initiatives underway to port operating systems to IA-64, the applications and market segments being targeted within each of those operating system environments, the participating Original Equipment Manufacturers (OEMs) and Independent Software Vendors (ISVs), and schedules. You'll learn what makes IA-64 an ideal fit for high-end computing environments on the various operating systems. You'll also learn how Intel is helping to make IA-64 the platform of choice for such environments by supporting industry-enabling efforts to establish compatibility guidelines and standards.

Developer Interface Guides

DIG64, UDIG, UDG-PI: Enabling Interoperability in Volume Markets

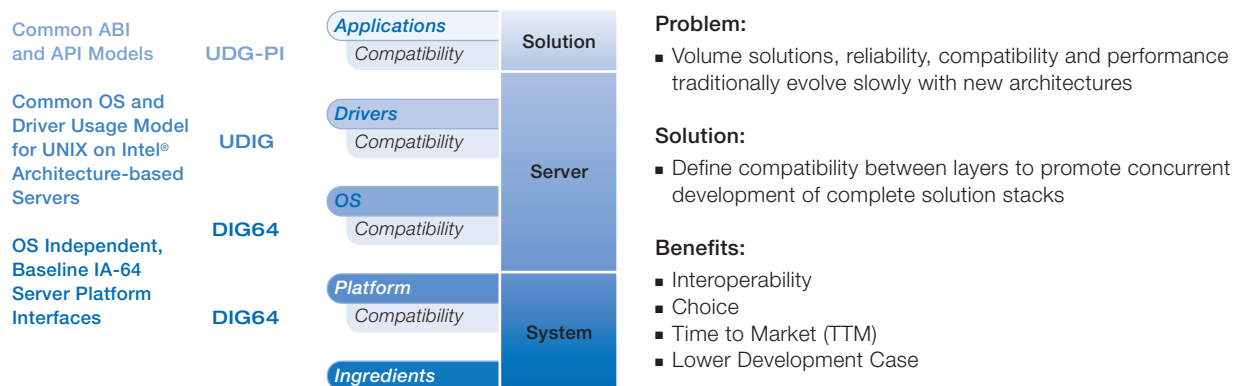


Figure 1: Leading software, system, and hardware vendors have collaborated on guidelines designed to help smooth the transition for developers working on server solutions for IA-64. (The Hardware Design Guide is not shown.)

Industry-enabling Efforts

Four of the industry-enabling efforts to establish compatibility guidelines and standards predominate: the “Developer’s Interface Guide for IA-64 Servers,” an operating-system-independent definition of hardware/software compatibility; the “UNIX* Developer’s Interface Guide for IA-64 Servers,” which specifies common building blocks and hardware interfaces supported across multiple UNIX environments; the “UNIX Developer’s Guide—Programming Interfaces,” which specifies interfaces and services tailored to infrastructure and business applications; and the “Windows NT* Hardware Design Guide,” which specifies design requirements for applications based on 64-bit Windows NT Servers.

Finally, you’ll learn how all of these endeavors can help to support porting efforts within your own organization and the steps developers can take to optimize applications for each of these operating systems on IA-64.

Developer’s Interface Guide for IA-64 Servers (DIG64)

In developing the DIG64, dozens of vendors have worked to provide a new industry definition of compatibility for server solutions based on IA-64. A key objective of this collaboration is to help developers manage legacy technologies and get to market fast with robust, interoperable solutions. Toward this objective, the DIG64 outlines baseline system building blocks and software interfaces for servers based on the Intel Itanium processor and subsequent members of the IA-64 family.

Developers can use the DIG64 guidelines as a reference to a common set of components, interfaces, and implementation requirements chosen from technology, standards, and initiatives that are already well established in the industry. Without the DIG64, these developers might easily spend countless months trying to converge on a set of common interfaces from among the hundreds of possible combinations of industry standards and initiatives.

The DIG64 guidelines define the following system building blocks, interfaces, and programming conventions for servers based on IA-64 and system-level software such as the operating system and firmware:

- Core system components such as the processor, chipset, memory, I/O bus, and server-management hardware
- Interfaces to peripheral devices for networking, communications, and storage.
- Low-level firmware interfaces to the operating system for system configuration and boot and runtime services.

Note that the DIG64 does not create new standards and interfaces, but instead selects components and interfaces from already existing technologies. To ensure interoperability, the DIG64 also specifies implementation requirements for each specification or standard.

DIG64: Scope and Content**Firmware Interfaces**

(Configuration, Pre-OS, OS Run-time, Platform)

Core System Components

(Processor, Chipset, Memory, I/O bus, Server Management)

Component Interfaces

(Networking, Communications, Storage)

Technology Migration

(Legacy Technologies, Replacement Technologies)

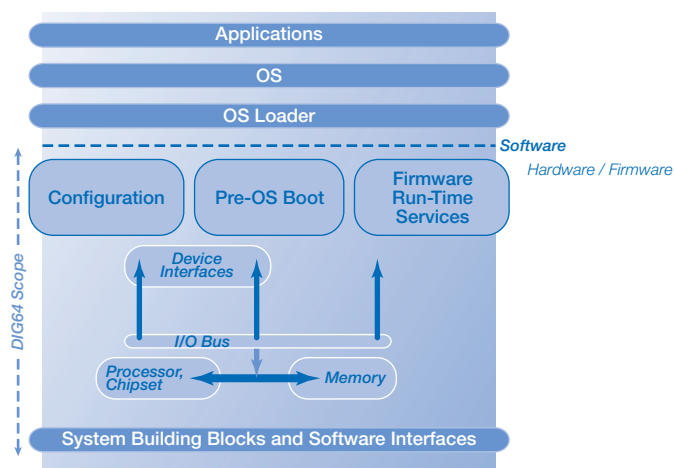


Figure 2: By defining baseline system building blocks and software interfaces and a systematic approach to technology migration, the DIG64 simplifies development of compatible IA-64 server systems.

To provide vendors latitude in implementation, the DIG64 includes a three-level hierarchy of required, recommended, and optional guidelines. DIG64 Release 1.0, which is currently available, pertains to servers based on the Itanium processor. Subsequent releases will address future processors as they are developed.

The DIG64 was produced by a group founded by Compaq, Dell, Fujitsu-Siemens, Hewlett-Packard, IBM, Intel, and NEC, and including dozens of other platform, operating system, firmware, and peripheral vendors. Reflecting this broad range of support, the DIG64 is operating-system independent, promoting cross-platform interoperability among servers running Windows® 2000 and Novell Modesto as well as Linux and other UNIX operating systems.

To download the initial release of the DIG64, to learn how your organization can become a DIG64 Adopter, or for more information in general, go to <http://www.dig64.org>.

UNIX Developer's Interface Guide for IA-64 Servers (UDIG)

The UNIX Developer's Interface Guide for IA-64 Servers (UDIG) is an industry program promoted by Intel and the leading UNIX operating-system and hardware vendors. The key objective of these vendors is to reach agreement on a set of common interfaces between UNIX operating systems and server hardware and devices without inhibiting the ability of UNIX vendors to effectively differentiate their products.

Another objective is to reduce obstacles to development, porting, and purchase of server solutions. To the vendors promoting the UDIG, this means developers would be faced with fewer and shorter ports so they could more easily focus on product differentiation. The UDIG also is designed to expand the choice of products in the market and reduce IT qualification cycles.

Both operating-system vendors and device vendors are collaborating on the UDIG effort. From the former group are Compaq, Hewlett-Packard, IBM, SCO, and Sun; and from the latter group are Adaptec, Intel, Interphase, LSI, Mylex, Phoenix Technologies, and Qlogic.

To learn more about UDIG, go to http://developer.intel.com/design/servers/dev_guides/udig/index.htm.

UNIX Developer's Guide—Programming Interfaces (UDG-PI)

The UNIX Developer's Guide—Programming Interfaces (UDG-PI) is a collaborative, multicompany effort to develop and publish a comprehensive set of application programming interfaces (APIs) and services for a high-volume, enterprise-class UNIX operating system. The UDG-PI also defines an application binary interface (ABI) for the Itanium processor that is designed to enable applications and middleware to run on UNIX systems from a wide range of manufacturers.

UNIX Developer's Guide Definition

A comprehensive set of application programming interfaces (APIs) and an application binary interface (ABI) for a high-volume, enterprise-class UNIX

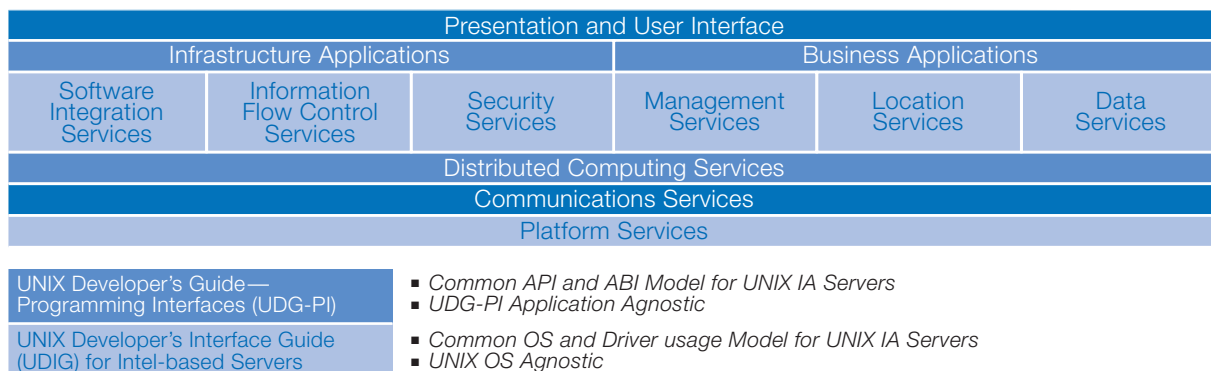


Figure 3: The UDG-PI specifies APIs, an ABI, and services tailored to infrastructure and business applications.

UDG-PI is designed to help hardware developers, system integrators, and vendors of operating systems, BIOS, and peripherals to create design conversions and designs based on a common framework; to program to common interfaces; and to use software development kits, device development kits, and reference implementation to accelerate product development. The goal is enhanced compatibility, interoperability, reliability, and scalability; reduced system costs; and a broader choice for IT departments and UNIX users.

The companies behind the UDG-PI effort are Intel, IBM, other UNIX operating-system vendors, and key ISVs. To learn more about UDG-PI, go to <http://www.projectmonterey.com/news.html>.

Hardware Design Guide for Windows NT* Server (HDG)

Co-authored by Intel and Microsoft, the Hardware Design Guide for Windows NT Server (HDG) is available to help engineers who are building Win64-based server systems, expansion cards, and peripheral devices. HDG specifies design requirements for classes of systems that will run any version of the Windows NT Server and addresses the following issues:

- Basic design alternatives for both small office/home office and enterprise servers.
- Requirements for implementing the OnNow design initiative, including those related to the Advanced Configuration and Power Interface (ACPI) specification, Plug and Play device configuration, and power management in server systems.
- Implementation of devices supported under Windows NT Server.

- Manageability features such as automation of administrative tasks and centralized control.

To learn more about HDG, go to <http://developer.intel.com/design/servers/desguide/index.htm>.

Major Operating System Initiatives

For years, the Intel® Architecture (IA) has supported many operating systems, and IA-64 is no exception. As described in the following, Intel is working closely with major initiatives now underway to port existing operating systems to the IA-64 architecture and, in one case, to create a new operating system for the platform. Here are a few of those initiatives:

- HP-UX:** A 64-bit port of HP-UX, Hewlett-Packard's implementation of UNIX.
- Linux:** A single, unified 64-bit version of Linux.
- Modesto:** A new 64-bit server operating system from Novell.

- **Monterey:** A single UNIX product that is being jointly developed by IBM and SCO and that includes UNIXWare 7 and Dynix/ptx for IA-32 platforms, Monterey-64 for IA-64 platforms, and AIX for POWER systems.
- **Windows 2000:** A 64-bit version of the Microsoft Windows 2000 operating system.

Each of these initiatives targets certain applications and market segments, is supported by certain OEMs and ISVs, and specifies certain conventions for the porting of applications. In the remainder of this document, you'll find more information on these topics along with schedules and links to tools, software development kits, and the respective operating systems themselves.

HP-UX (Hewlett-Packard)

Overview

The Hewlett-Packard HP-UX 11 operating system runs on both IA-64 and the company's proprietary Precision Architecture (PA)-RISC architecture. Compatibility extends to both source and binary for applications that are not sensitive to the architecture or operating-system implementation. In addition, HP-UX utilities, commands, user interfaces, and shell scripts are the same in both environments: IA-64 and PA-RISC. Data Formats are also compatible between the two environments.

Here are the primary differences between HP-UX on IA-64 and HP-UX on PA-RISC:

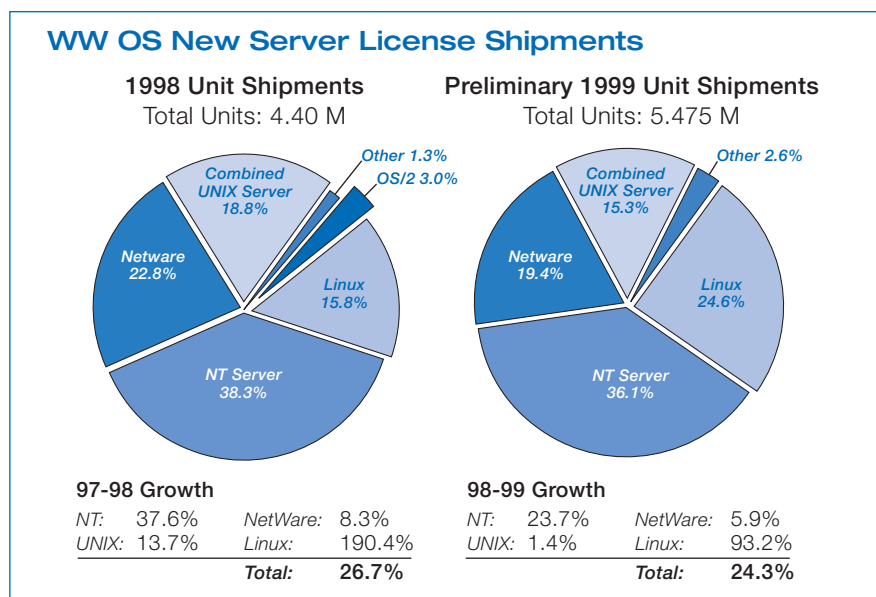


Figure 4: The operating systems with the largest presence in server-based applications are also the operating systems with the most ambitious IA-64 porting initiatives behind them. Note also that with Windows NT, Linux, and NetWare all running on IA and more than half of all UNIX shipments on IA, it is the architecture of most server shipments.

Note: New data will be available in May 2000.

- The runtime architecture has some slight differences to support the IA-64 hardware but only for native IA-64 applications. The PA-RISC runtime architecture is also provided with HP-UX on IA64 and used when PA-RISC binaries are run on IA-64.
- The object-file format is Executable Linking Format (ELF) for IA64 and PA64, while the System Object Model (SOM) object-file format for older PA32 objects is supported also. This allows users to run their existing PA32 applications on IA64 without having to recompile.
- The debug-information format used on IA64 is somewhat different from the debug-information format used on PA-RISC. This is to bring HP-UX on IA-64 closer to other UNIX operating systems on IA-64 for the purpose of simplifying tool development.

Target applications

Hewlett-Packard's implementation of UNIX, HP-UX, on IA-64 is ideally suited for secure e-services, technical computing data-centers, enterprise-level database, and business intelligence applications.

Participating OEMs and ISVs

Hewlett-Packard is working with more than 500 enterprise ISVs and customers that are porting and/or certifying their solutions for HP-UX on IA-64 through programs providing help with planning, technical support, and developer toolsets. Cross-development environments for PA-IA development are available, and an IA Software Transition Kit can be downloaded today from the Web sites.

Schedule

The HP-UX operating system and tools are scheduled to be available for end-user shipments on IA-64 by the fourth quarter of 2000. Beta releases for ISVs will be available in the third quarter.

For more information

To begin a port of applications designed for HP-UX on PA-RISC to HP-UX on IA-64, find the UNIX 98 APIs at <http://www.unix-systems.org/apis.html> and related information at <http://www.unix-systems.org/unix98.html>. To download the HP-UX Software Transition Kit go to <http://www.software.hp.com/stk>.

To learn more about preparing software for porting to HP-UX on IA-64, go to <http://devresource.hp.com/devresource/Events/HPWorld99/PreplA64/PreplA64Index.html>.

For more information in general, go to <http://developer.intel.com/design/ia64/IDFHP-UxLab/index.htm>.

Linux (Trillian Project)

Overview

More than 90 percent of all Linux installations are running on the Intel architecture, and Linux is strong in market segments where 64-bit capabilities matter most. Because of this, the porting of Linux to IA-64 is a significant initiative and one involving Intel and a number of other participants. Known as the Trillian Project, its goals are providing a single, unified IA-64 Linux port, optimizing the port, and making it Open Source in time for production of the Intel Itanium processor.

In addition to the standard features of Linux, the Linux port for IA-64 supports a variety of Intel requirements and general enterprise capabilities such as Symmetric Multiprocessing (SMP), Streaming SIMD Extensions (SSE), Wired for Management (WfM), Intelligent Platform Management Interface (IPMI), Advanced Configuration and Power Interface (ACPI), clustering, large memory, large file systems, and performance monitoring. The port will be backward compatible with IA-32 and will run most IA-32 binaries without modification.

Target applications

Linux holds 40 percent of the ISP market, is a growing force in e-Commerce infrastructure, and is an emerging force as a database-server platform. These factors make Internet service applications a natural target for the IA-64 version of Linux.

Participating OEMs and ISVs

In addition to Intel, companies and organizations participating in the Trillian Project include Caldera, CERN, Cygnus Solutions, Hewlett-Packard, IBM, Red Hat, SuSE, SGI, TurboLinux, and VA Linux Systems.

Schedule

Linux and tools are scheduled to be available on IA-64 from the major distributors in the third quarter of 2000. That port will be incorporated into the standard Linux tree.

For more information

To learn more about the Linux for IA-64 and the Trillian Project go to <http://developer.intel.com/design/ia64/IDFLinuxLab> or <http://www.linuxia64.org>.

Modesto (Novell)

Overview

Novell is working with Intel to create a new operating system, code-named Modesto, targeting IA-64 and focusing on the Internet infrastructure.

Modesto's Winning Architecture

Modesto Architecture Designed for High-performance Network Services, Applications and Java Eliminates Unnecessary Layers and Gets Software as Close to the "Metal" as Possible

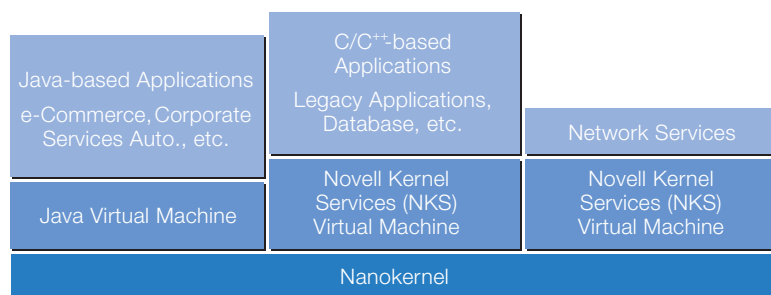


Figure 5: Modesto is characterized by one of the industry's first nanokernel-based designs.

Modesto is a single-address-space operating system with a minimal nano-kernel designed to support primitive abstractions that permit efficient layering of higher-level programming environments. In contrast to general-purpose operating systems, Modesto avoids the use of a general infrastructure and instead partitions functions that are specific to certain services into separate and easily optimizable “virtual machines.” These virtual machines run on top of the common services layer provided by the nanokernel, leading to a modular and tunable 64-bit system that is also capable of running native NetWare 5 services and applications.

Modesto also supports a new high-performance C/C++ programming environment for native 64-bit operation. The APIs for this environment can be targeted for both 32-bit and 64-bit platforms. As for Java, once it is fully optimized for the new operating system and the IA-64 environment, Novell will provide a high-performance and scalable server-side Java implementation. The Java Virtual Machine will be tightly integrated with the system software in ways not available to other vendors while maintaining full compatibility.

Target applications

Target applications for Modesto include high-performance directory-enabled and Internet-based services, applications, appliance servers, and cache servers.

Participating OEMs and ISVs

Novell is partnering with industry-standard tool providers, such as EPC, to ensure that developers will have the tools they need to create their applications, to enhance the development capabilities on NetWare 5, and to provide a clear path to exploit the 64-bit design of Modesto. Novell will support an industry-standard executable format on Modesto to enable developers to use tools from multiple vendors. The Developer Toolkits from Novell will become available as the environment matures.

Schedule

The Novell Modesto platform and tools are scheduled to be available on IA-64 by the fourth quarter of 2000.

For more information

To learn more about Modesto, go to <http://www.novell.com/whitepapers/iw/modesto.html>. At the main Novell Web site, <http://www.novell.com>, see in particular documents referring to Novell Kernel Services (NKS), which is integral to porting to Modesto.

Monterey (IBM and SCO)

Overview

Monterey is part of Project Monterey, an initiative led by IBM and SCO and with participation from Intel and other major hardware and software companies. The goal of the project is to deliver a high-volume, enterprise-class UNIX product line that will run on IA-64 as well as IA-32 and IBM POWER platforms.

Central to Project Monterey is a strategy to enable developers to standardize APIs and ABIs and to build a single, fully optimized source tree. This source tree will target all three architectures through a simple “compile and go” method. The idea is to give software vendors a commercially designed and supported enterprise-class UNIX adaptable from the department to the data center with a single source tree.

Target applications

Monterey is being designed to target applications in the areas of e-Commerce, business intelligence, supply-chain management, customer-relationship management, consolidated messaging, Internet infrastructure, and telephony.

Participating OEMs and ISVs

As of early 2000 Project Monterey had the support of more systems vendors than any other UNIX platform. In addition to Intel, major OEMs, including ACER, Bull, Compaq, IBM NUMA-Q (formerly Sequent), ICL, Netfinity, Samsung, and Unisys, have endorsed Project Monterey. In addition, more than 100 ISVs have endorsed Project Monterey and are making plans to port their products to Monterey/64. The Monterey team is working actively with ISVs, IHVs, and customers to ensure availability of complete solutions at Monterey launch.

Schedule

The Monterey operating system and tools are scheduled to be available on IA-64 in the fourth quarter of 2000.

For more information

To learn about porting an application to Monterey, go to <http://www.projectmonterey.com/faqs.html> or download a porting guide available at <http://www.ibm.com/servers/monterey/pdfs/migrate.pdf>. To learn more in general about Project Monterey, go to <http://www.projectmonterey.com>.

Windows 2000 (Microsoft)

Overview

Intel has worked closely with efforts at Microsoft to develop a 64-bit version of the Windows 2000 operating system. The initial launch of that system came in August 1999, when developers announced a successful boot on a prototype IA-64 processor.

The 64-bit Windows 2000 operating system is fully compatible with the 32-bit Windows 2000 and Windows NT Server 4.0. This includes compatibility between the Win64 API and the Win32 API, which helps to maintain a single source-code base and supports the running of 64-bit and 32-bit binaries concurrently, as long as the binaries are not mixed in a single process.

In addition, the 64-bit Windows 2000 development environment is designed to support the same feature set as the 32-bit Windows development environment. This support includes the same user interface, C programming data models, networking, security, graphics, multimedia, directory service, Plug and Play, and tools features.

Target applications

The 64-bit Windows 2000 operating system is designed to provide high availability, advanced scalability, and large-memory support for e-Commerce, large-scale online transaction processing, high-end graphics, complex mathematics, and high-performance multimedia.

Schedule

Windows 2000 and tools are scheduled to be available on IA-64 in the fourth quarter of 2000. Microsoft SQL Server also is scheduled to be available on IA-64 at the time. Other key BackOffice family applications are scheduled for IA-64 availability in 2001.

For more information

For more information on the data types supported by the Win32 API, go to http://msdn.microsoft.com/library/psdk/psdkref/type_8uk3.htm. For a Windows 2000 Device Driver Toolkit go to <http://www.microsoft.com/ddk/W2kDDK.htm>. To learn more about porting existing applications and developing new applications for 64-bit Windows, go to <http://www.microsoft.com/windows2000/guide/platform/strategic/64bit.asp> or see "Getting Ready for 64-bit Windows" at http://msdn.microsoft.com/library/psdk/buildapp/64bitwin_410z.htm.

Heading in the Right Direction

If your organization is planning to port an application to IA-64, you are in good company. As detailed in this document, numerous operating-system and application vendors have been working steadily

to make their products available on the new architecture. This document covers only a small part of the work they are doing and the development resources available, but it should be enough to point you in the right direction. Note that for porting in particular, you may want to make use of another Intel document providing a step-by-step approach to preparing code. This IA-64 code-preparation checklist is available at <http://developer.intel.com/vtune/cbts/ia64tuts/clean/index.htm>.

For more information on porting and on the operating systems that will be available on IA-64 at the time of the Intel Itanium processor launch, go to <http://developer.intel.com/design/IA64/devinfo.htm>.



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